TABLE 1.—*Solar radiation intensities during August, 1916*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Santa Fe, N. Mex.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Aug. 1	......	1.35	1.23	1.19	1.16	1.11	......	......	......	......
7	......	......	1.07	1.00	0.93	0.87	......	......	......	......
9	......	1.14	1.04	0.98	0.92	0.85	0.80	0.75	......	......
26	......	......	......	......	1.18	1.13	1.07	1.05	1.01	......
28	1.44	1.30	1.24	1.20	1.15	......	......	1.03	1.00	......
29	1.35	1.28	1.20	1.13	1.07	1.01	0.96	0.91	0.87	0.83
31	......	1.40	1.33	1.26	1.19	1.13	1.08	1.04	1.00	0.97
Monthly means	(1.40)	1.29	1.18	1.13	1.09	1.02	0.98	0.96	0.97	(0.90)
Departure from 4-year normal	−0.03	−0.03	−0.04	−0.02	−0.01	−0.02	......	......	......	......

Sky-light polarization measurements made at Washington on nine days, with the sun at zenith distance 60°, give a mean of 50 per cent, and a maximum of 66 per cent on the 14th. This latter is only 1 per cent lower than the highest August polarization measurement ever obtained at Washington.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	8 a. m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.
1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*
Aug. 8	19.89	20.57	Aug. 8	15.11	14.10	Aug. 2	17.96	18.59	Aug. 1	9.14	9.83
14	9.14	13.13	9	13.13	13.61	3	16.20	16.79	7	8.81	10.59
17	14.60	18.59	11	13.61	13.13	4	17.37	17.96	9	9.14	7.87
18	14.10	16.20	12	11.81	12.24	8	12.68	13.13	26	7.29	7.87
19	14.60	16.20	16	11.10	14.60	10	17.37	17.96	28	6.76	5.79
20	15.11	17.57	18	20.57	17.37	11	12.24	14.10	29	8.48	9.83
22	18.59	23.60	23	10.21	8.81	12	13.61	17.37	31	8.48	7.29
23	17.37	16.20	24	10.21	10.21	15	17.37	18.59			
24	11.81	13.61	25	8.48	8.81	17	18.59	19.23			
25	13.61	14.10	28	7.87	7.04	18	15.11	16.20			
26	16.20	17.37	29	8.48	9.14	19	15.11	16.79			
28	16.79	10.97	30	9.83	13.13	21	14.60	15.11			
31	14.10	16.20				22	10.59	10.59			
						23	9.14	11.81			
						24	10.59	11.38			
						25	10.59	10.97			
						28	8.18	7.04			
						29	7.04	11.38			

Table 3 shows a deficiency of radiation at Washington during the first half of August, which was more than made up by the excess during the second half. At Madison there was an excess of radiation for the month amounting to 7.8 per cent of the average August total. At Lincoln there was a deficiency of radiation during the second decade, but the departures from the normal were slight during the first and third decades.

TABLE 3.—*Daily totals and departures of solar and sky radiation during August, 1916.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	Gr.-cal.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
1	491	363	305	−1	−115	−215	−1	−115	−215
2	616	547	618	126	72	101	125	−43	−114
3	375	312	625	−113	−161	110	12	−204	−4
4	349	294	612	−137	−177	100	−125	−381	96
5	402	388	580	−82	−81	70	−207	−462	166
6	368	565	472	−113	99	−35	−320	−363	131
7	528	594	331	49	130	−174	−271	−233	−43
8	535	600	609	59	139	107	−212	−94	64
9	371	606	458	−103	148	−42	−315	54	22
10	502	212	517	31	−243	20	−284	−189	42
11	236	521	257	−233	69	−233	−517	−120	−196
12	477	446	509	11	−3	17	−506	−123	−179
13	332	648	208	−131	202	−281	−637	79	−460
14	668	349	132	207	−94	−355	−430	−15	−815
15	406	227	494	−52	−213	10	−482	−228	−805
16	125	541	359	−330	104	−123	−812	−124	−928
17	550	479	604	98	44	125	−714	−80	−803
18	529	563	610	79	131	134	−635	51	−669
19	562	478	603	115	49	129	−520	100	−540
20	556	531	477	111	105	6	−409	205	−534
Decade departure				......	......	......	−125	+394	−576
21	461	505	560	19	82	92	−390	287	−442
22	535	259	458	95	−101	−7	−295	126	−449
23	313	560	526	−124	143	63	−419	289	−386
24	576	550	568	141	136	108	−278	405	−278
25	521	551	438	89	140	−19	−189	545	−297
26	527	430	311	97	22	−144	−92	567	−441
27	469	592	613	42	186	160	−50	753	−281
28	445	567	599	20	164	148	−30	917	−133
29	420	543	533	−3	143	84	−33	1,060	−49
30	430	514	213	10	116	−234	−23	1,176	−283
31	474	281	132	56	−114	−313	33	1,062	−596
Decade departure				......	......	......	+442	+857	−62
Excess or deficiency since first of year: gr.-cal.		......	......	......	......	......	−6,454	+2,705	......
Excess or deficiency since first of year: per cent.		......	......	......	......	......	−6.7	+2.8	......

HIGH HAZE OVER THE SOUTHWESTERN UNITED STATES DURING JULY TO SEPTEMBER, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated Weather Bureau, Washington, Oct. 2, 1916.]

The following is extracted from a communication by Mr. Ford A. Carpenter, in charge of the Weather Bureau office at Los Angeles, Cal., under date of September 7, 1916:

During the month of July, and especially during the latter part, red sunsets were common; but during the first decade of August both sunrises and sunsets were unusually brilliant. A note in the Daily Local Record describes a typical sunset as follows:

"*August 4, 1916.* Cloudy sunset. The sun set behind cirro-stratus clouds, which formed a low bank on the western horizon. As the sun set the western sky became lit with a yellow glow, which changed to orange, and finally to red."

A description is also given of brilliant sunrise and sunset colors that were observed from the top of Mount Wilson, Cal., on September 3 and 4, 1916, and Mr. C. G. Abbot of the Astrophysical Observatory of the Smithsonian Institution, who was then on Mount Wilson, is quoted as saying—

The presence of dust, probably volcanic, and which was responsible for the vivid colors of sunrise and sunset, greatly interfered with solar radiation work.

Mr. Carpenter further states that between July 28 and August 4, 1916, while on Mount Rainier, Wash., he observed each of the eight sunrises and sunsets, and there was a total absence of other than the usual twilight colors. He therefore infers that the dust cloud did not extend to this high latitude (47° N.).

In a letter of September 20 he forwards a note from Prof. A. E. Douglass, University of Arizona, relative to radiating shadows observed at that place on the underside of the dust layer. It appears that these shadows are first seen 16 minutes after sunset, and continue about 10 minutes, and were best observed on September 14 and 15. Prof. Douglass identifies them as shadows from mountain peaks or clouds in the range running south from San Diego, and about 300 miles from Tuscon in an air line. From the angular height of the shadows he computes the dust layer to be from 12 to 15 miles above the surface.

It does not seem possible to connect this dust or haze with the haze that produced the brilliant twilight colors that were generally observed in the vicinity of Washington, D. C., at the end of July, and also at Lincoln, Nebr., at about the same time.[1] The pyrheliometric observations obtained at Santa Fe, New Mex., Lincoln, Nebr., Madison, Wis., and Washington, D. C., and summarized on another page, give no indications of unusual haze during August. Up to the date of writing this note the Weather Bureau has been unable to learn of a recent volcanic eruption of sufficient violence to cause a haziness of the upper atmosphere of the character observed. We shall be glad to receive further information relative to this interesting phenomenon.

The following is the substance of an additional note from Mr. Carpenter, under date of October 7, 1916:

It is reported from the Lick Observatory, Mount Hamilton, Cal., that red sunsets have been observed since the first week in August. On many nights in August and September the sky was rather thick, and the Milky Way did not stand out as prominently as usual. This and the red sunsets have been interpreted by the observatory to mean that the atmosphere has contained an abnormal amount of finely divided dust.

Red twilight glows have also been reported from San Bernardino and San Diego, Cal., and Phoenix, Ariz. At Tucson, Ariz., no red sunsets have been observed since the middle of September, but here at Los Angeles, in spite of unusually heavy rains during the first few days of October, they do not appear to have decreased in frequency. Whenever the mornings and evenings have been clear the sky has been suffused with a red glow.

In Switzerland.—Added significance is given the above observations by the following note quoted from the British Meteorological Office circular.[2]

Dr. Maurer, director of the Swiss Meteorological Institute, writes from Zurich that since the middle of July the atmosphere in the high Alps has shown noteworthy *optical deterioration*, indicated by the extension of the aureole round the sun, to as much as 140° in diameter at the end of August, and by a true brown Bishop's ring, visible on August 3 and 4. The cause of the deterioration is still in doubt. Corresponding phenomena in 1883–4, 1902–3, and 1912 were attributed to violent volcanic eruptions, but no reports of volcanic eruptions have come to hand this year. Whether or not the cumulative effect of gunfire in the course of two years is equivalent to that of a volcanic eruption there are no figures to show.

[1] *See* MONTHLY WEATHER REVIEW, July, 1916, 44:382. After the publication of the July REVIEW several correspondents in Virginia also reported brilliant sunsets at the end of July.—*H. H. K.*

[2] *Great Britain. Meteorological Office.* Meteorological Office circular No. 4 [London], Sept. 21, 1916. p. 4.

ATMOSPHERIC REFRACTION AT MOUNT HAMILTON, CAL.[1]

Aside from conditions which actually conceal objects or make the images so unsteady that accurate observation is impossible, the atmosphere is of importance to astronomy and geodesy because of its refractive power. Professor Simon Newcomb [2] writes as follows concerning atmospheric refraction:

The refraction of a ray of light by the atmosphere as it passes from a heavenly body to an observer on the earth's surface, is called "astronomical [refraction]." A knowledge of its amount is a necessary datum in the exact determination of the direction of the body. In its investigation the fundamental hypothesis is that the strata of the air are in equilibrium, which implies that the surfaces of equal density are horizontal. But this condition is being continually disturbed by aerial currents, which produce continual slight fluctuations in the actual refraction, and commonly give to the image of a star a tremulous motion. Except for this slight motion the refraction is always in the vertical direction; that is, the actual zenith distance of the star is always greater than its apparent distance. The refracting power of the air is nearly proportional to its density. Consequently the amount of the refraction varies with the temperature and barometric pressure, being greater the higher the barometer and the lower the temperature.

At moderate zenith distances, the amount of the refraction varies nearly as the tangent of the zenith distance. Under ordinary conditions of pressure and temperature it is, near the zenith, about one second [of arc] for each degree of zenith distance. As the tangent increases at a greater rate than the angle, the increase of the refraction soon exceeds one second for each degree. At 45° from the zenith the tangent is 1 and the mean refraction is about 58 seconds. As the horizon is approached the tangent increases more and more rapidly, becoming infinite at the horizon; but the refraction now increases at a less rate, and, when the observed ray is horizontal, or when the object appears on the horizon, the refraction is about 34 minutes, or a little greater than the diameter of the sun or moon. It follows that when either of these objects is seen on the horizon their actual direction is entirely below it. One result is that the length of the day is increased by refraction to the extent of about five minutes in low latitudes, and still more in higher latitudes. At 60° the increase is about nine minutes.

The atmosphere, like every other transparent substance, refracts the blue rays of the spectrum more than the red; consequently, when the image of a star near the horizon is observed with a telescope, it presents somewhat the appearance of a spectrum. The edge which is really highest, but seems lowest in the telescope, is blue, and the opposite one red. When the atmosphere is steady this atmospheric spectrum is very marked and renders an exact observation of the star difficult.

Again writing of the difficulties connected with this study, he says:[3]

There is perhaps no branch of practical astronomy on which so much has been written as on . . . [refraction] and which is still in so unsatisfactory a state. The difficulties connected with it are both theoretical and practical. The theoretical difficulties . . . arise from the uncertainty and variability of the law of diminution of the density of the atmosphere with height and also from the mathematical difficulty of integrating the equations of the refraction for altitudes near the horizon after the best law of diminution has been adopted.

In spite of the difficulties, however, all accurate position work demands that the observed positions of stars be corrected for atmospheric refraction. This necessity has led to the construction of "refraction tables" from which a correction for atmospheric refraction can

[1] *Comstock, G. C.* Reduction tables for the Lick Observatory III, IV, and V (1883) Univ. Cal. publ. Lick observ., 1:221–258 (Sacramento, Supt. State Printing, 1887).
Tucker, R. H. The refraction, *in* Meridian circle observations made at the Lick Observatory 1896–1901. Univ. Cal. publ. Lick observ., 6:150–155. (Sacramento, Supt. State Printing, 1903.)
Tucker, R. H. The refraction, *in* Meridian circle observations made at the Lick Observatory 1901–1906. Univ. Cal. publ. Lick observ., 10:14–17. (Sacramento Supt. State Printing, 1907.)
Crawford, R. T. On astronomical refraction. Univ. Cal. publ. Lick observ., 7 [1902–1911]: (part 6) 159–216, [1909]. (Sacramento, Supt. State Printing, 1913.)
Tucker, R. H. Diurnal variation in the refraction at Mt. Hamilton. Univ. Cal. publ. astron., Berkeley, 1913, 7:130–139. (Lick Observ. bul. 231.)
Tucker, R. H. The diurnal variation of the refraction. Astron. soc. Pacific publ., San Francisco, 1916, 28:69–73.
——— Recent observations on the diurnal change in the refraction at Lick observatory. Ibid., 28:199–200.

[2] *N[ewcomb], S.* Astronomical refraction. Encyc. Britannica, ed. 11, New York, 1911. 23:29.

[3] *Newcomb, S.* A compendium of spherical astronomy. New York, 1906, p. 223.
In this connection, especially for the Pacific coast mountains of the United States, see *Schott, C. A.* "Hourly values of the coefficient of refraction," *in* The transcontinental triangulation and the American arc of the parallel, Washington, 1904, p. 254–256. (U. S. Coast and Geodetic Survey, Special publ. No. 4.)